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TECHNICAL RESEARCH NOTE 122

Human Factors Research
in Image Systems--
Status Report, 30 June 1962

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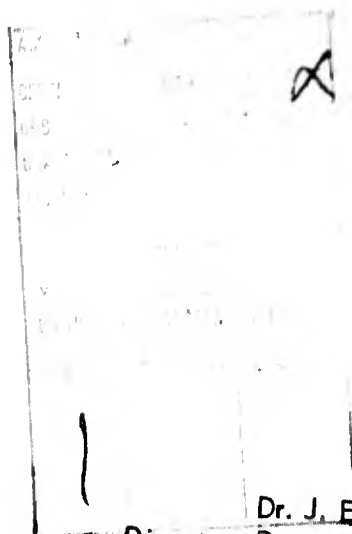
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Image Systems--00

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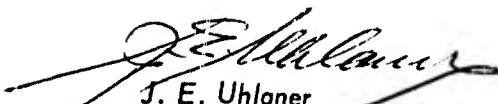
HUMAN FACTORS RESEARCH IN IMAGE SYSTEMS--STATUS REPORT, 30 JUNE 1962

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June 1962

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BRIEF

HUMAN FACTORS RESEARCH IN IMAGE SYSTEMS--STATUS REPORT, 30 JUNE 1962

Requirement:

The Army has a requirement for the best utilization of the human component in image systems, with emphasis on the development of the Tactical Image Interpreter Facility (TIIF) and real-time and near real-time image systems.

Procedure:

A research program, initiated 1 July 1960, was organized around two general questions: What skills, abilities, and techniques are necessary in the successful performance of the Army's image systems? How can the Army best utilize its interpreter resources to improve the intelligence information output of image systems? Four research subtasks were delineated:

1. The identification of basic human factors in the development of the TIIF
2. Information extraction from images of near real-time systems
3. Techniques for interpreting TV imagery
4. Improved procedures in communication of intelligence information

Accomplishments to Date:

During FY 1962, the task was involved in two major efforts: (1) the development of performance measures needed for the real-time and near real-time studies; and (2) a study to determine the comparative effectiveness of prints, positive transparencies, and negative transparencies for purposes of information extraction in connection with the TIIF.

Utilization of Findings:

Potential end products include (1) determination of the utility of an electronic image reversal device, (2) determination of optimal size and composition of selected image interpreter units, (3) improved communications to and from interpreters, and (4) utility of real-time image systems.

HUMAN FACTORS RESEARCH IN IMAGE SYSTEMS--STATUS REPORT, 30 JUNE 1962

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HUMAN FACTORS RESEARCH IN IMAGE SYSTEMS--STATUS REPORT, 30 JUNE 1962

Future warfare is expected to place particular emphasis upon very rapid tactical and strategic information feed-back to the tactical commander. Because image interpretation is one of the Army's most fruitful sources of such intelligence, the Army is developing and introducing various tools, devices, and image systems--new sensors, platforms, transmission systems, 'real-time' (TV-type) and near 'real-time' image systems--all designed to extend the commander's ability to obtain timely and accurate information. The new systems have the capability of generating large volumes of imagery, from which the human element must extract accurate, timely, complete, and relevant information.

The ultimate effectiveness with which information is returned to the commander depends critically upon the ability of the personnel assigned to manipulate and manage each new tool, device, or system. The capabilities of human performance are challenged by requirements for high mobility and speed in image interpretation.

The problems that require attention are vast, particularly when the development of new sensor platforms, exotic sensors, display devices, and data processing equipment are taken into consideration. These problems are concerned with

1. efficient reduction in volume of imagery that must be processed
2. processing the imagery to derive necessary intelligence with the attributes of accuracy, timeliness, completeness, and relevance
3. recording, retrieval, and dissemination of processed intelligence

The effort of the USAPRO IMAGE SYSTEMS Task will be directed for the immediate future toward the integration of man into some of these highly complex man-machine intelligence systems with particular emphasis on the development of the Tactical Image Interpreter Facility (TIIF) and real-time and near-real time image systems.

PURPOSES OF THIS REPORT

The major purposes of this report are:

1. to describe the research program and objectives of the USAPRO IMAGE SYSTEMS Task
2. to indicate the kind of payoff in intelligence output that can result from human factors research in image systems
3. to describe the current status of the task effort

THE IMAGE SYSTEMS TASK

The effort of the IMAGE SYSTEMS Task is closely tied to the development of a number of systems designed to meet the Army's need in the eventuality of future wars. (See Appendix A for typical system research approaches) The Tactical Image Interpreter Facility and the drone systems with their electronic image transmittal subsystems are among these systems. In addition, the Task is also concerned with research on systems currently in the planning. In this category are studies dealing with TV as a possible real-time sensor, and with computer devices for the storage, retrieval, and dissemination of information.

In planning the research, the psychological requirements have been broken down into two broad problem areas. The first is concerned with the nature of the specific activity required of the interpreter, for example, the extraction of information from images. The specific question to be answered is: What skills, abilities and techniques are necessary to accomplish the required tasks? The second problem area relates to performance in the context of Army operations. How can the Army best take advantage of its interpreter resources and talents to improve intelligence information output? In order to answer these two broad questions, four research subtasks were established:

- Subtask a. The Identification of basic Human Factors in the Development of the Tactical Image Interpreter Facility (TIIF).
- Subtask b. Procedures for the Extraction of Information from Image Displays of Near Real-Time Systems.
- Subtask c. Techniques for Interpreting TV Imagery.
- Subtask d. Improved Procedures in Communication of Intelligence Information.

The Identification of Basic Human Factors in the Development of the Tactical Image Interpreter Facility (TIIF)

The TIIF is intended to be a mobile physical working environment for the interpreter team. Currently, three TIIF's are being planned for development and use in mid-range, long-range, and very long-range time frames by the Systems Techniques Branch of the Surveillance Department, U. S. Army Signal Research and Development Laboratory. The Army will soon let a contract for the construction of a prototype mid-range facility which will be furnished with off-the-shelf equipment. In order to provide proper human factors support for the development of the TIIF's, the U. S. Army Personnel Research Office will work very closely with the Advanced Techniques Branch, The Army Combat Surveillance Agency, and the intelligence community for the purpose of attacking meaningful problems and securing the necessary equipment and personnel support to conduct the studies.

In general, two sets of problems require special attention in the development of the TIIF's. The first concerns the utility of various items of equipment, and the other the layout of equipment and operations in the van itself. Both are critical because of the severe space limitations imposed by the size of the van. These studies are expected to provide information as to work methods, techniques, numbers of various items of equipment, and numbers and specialties of personnel to man the vans.

Utility of Equipment. The need for determining the utility of various items of equipment is obvious. If an item of equipment does not contribute to the output, or is no better than another simpler and smaller one, then the item is not wanted. Within this context, the IMAGE SYSTEMS Task is conducting a study to determine the relative effectiveness of the interpretation of positive transparencies, negative transparencies, and positive prints (both stereo and non-stereo). The findings of this study will provide some information concerning the need for an image reversal device that can instantaneously transform negative transparencies into positives and vice versa.

Similarly, studies are contemplated to determine the need for rectifying panoramic and oblique imagery. As new equipment and new devices are considered for inclusion in the TIIF's, additional studies of this type will be undertaken.

Layout of Equipment. The problem area dealing with the layout of equipment and operations in the van must await the availability of the van for testing purposes. As applicable results of IMAGE INTERPRETATION Task studies become available, they will be used for initial planning purposes. However, an empirical check is needed on the adequacy of the planning. The type of study contemplated here would impose various workloads on the TIIF system to establish the best possible flow of operations. As workloads are increased and demands for information are systematically varied, various constriction points in the system will become apparent. Corrective steps, if needed, such as providing additional copies of certain items of equipment, determining different ways of doing the work, or varying the personnel complement of the van, can then be taken.

Procedures for the Extraction of Information from Image Displays of Near Real-Time Systems

In a war of high mobility, timeliness of information takes on special significance because much of this information is highly perishable. The Army is currently trying to improve the reaction time of its forces, and to provide a faster flow of intelligence information to make these forces more effective. Among the systems designed to do this are the several drone systems. The primary purpose of these drone systems is to transmit to the ground, through electronic subsystems, an image record of the area surveyed, in case the drone does not return. A secondary purpose is to increase the speed with which images are presented to the interpreter for information extraction. Therefore, the extraction of information under quick-time conditions--conditions that approximate

those under which the photography will be displayed--becomes a research area of prime concern. These studies will provide information on the utility of intelligence information extracted. They will explore ways and means to improve the output, and they will attempt to get at the problem of how best to use the information provided. Findings of these studies will not be limited to drone systems per se. They will also provide information more generally on quick-time interpretation.

Drone systems are designed to fly over areas of interest and carry the sensors to take the pictures. In the ground sensor terminal the interpreter sits in front of a photographic display presenting image transparencies with a format of 5" x 5". The most likely mode of operation is the "scan slew" mode which transmits every third frame taken. This still provides for continuous area coverage, since the camera is set to produce the 66% overlap to permit stereo viewing. Therefore, unless the operator decides to use the "continuous scan" mode, the photography will be non-stereo. However, even with scan slew, the operator faces an increasing time lag, since the electronic scanning of the image prior to transmission requires approximately eight seconds per frame and the camera can be set to produce up to three frames per second, depending upon the altitude and speed of the drone and the focal length of the lens. Either way, the interpreter will have only a few seconds to view a frame before the next one appears, unless he decides to hold the frame for a longer period. Such delay, of course, increases the lag time for the viewing of subsequent frames. During the time a frame is displayed, the interpreter must determine whether or not there is something worth reporting in terms of the essential elements of information (EEI) established by the mission, he must identify the object, and he must set the frame aside for object location.

In the ground sensor terminal there is also a plotting board. This board provides information on the approximate location of the drone. The plotting board consists of a map of the area over which the drone is programmed to fly. Over the map is a sheet of clear acetate. On this acetate overlay, a pencil mounted in an arm controlled by tracking radar draws a flight trace of the course of the drone as it flies its mission. This information can then be correlated with the specific frames selected for information extraction. Since the plotting board information is more immediate than the receipt of the frame (lag time for receipt and reproduction of images increases continuously as frames are transmitted), interpolation is required to associate each selected frame with the approximate location. An interpreter, probably not the same one who first viewed the photography, must then locate each frame on the map, from known terrain and other features, and then derive coordinates for the objects of interest.

Essentially, then, in a quick-time setting, the interpreter must screen the photography for frames of interest, select those items that help to satisfy requirements of the EEI, identify the objects, and provide coordinates.

For purposes of research this subtask has been divided into four research areas, each of which consists of numerous projects.

Identification of Basic Psychological Factors in Quick-Time Interpretation. A number of problems and questions arise in connection with the performance of the average interpreter who will be called upon to work in a quick-time setting. Answers to these questions and problems would have an impact on the ground sensor terminal design, and the manning and operations of this facility.

1. How much can we expect from the interpreter? How much information does he provide? How much does he miss? How accurate is this information? What is the largest number of EEI-type items he can respond to? As the list of EEI-type items is increased from very few to a dozen or more, what happens to interpreter output?

Answers to these questions would provide information on the number of displays needed and/or operations in the ground sensor terminal. For example, if performance were to drop appreciably with a request for more than three items of the EEI type, another viewing display would be needed for a different interpreter, who would look for different objects. Or the same film would have to be viewed repeatedly for different sets of objects.

2. Another study would explore the amount of time required to view a given frame to determine whether or not it is worth interpreting. This study would address the problem of film-movement rate across the viewer to achieve both accuracy and completeness of the information extracted.

3. Still another study would attempt to determine the relative effect of machine-paced vs self-paced presentation of images on the accuracy and completeness characteristics of interpreter output.

4. A different study is designed to determine whether or not the primary record returned in the drone needs to be interpreted if the transmitted record (which is of poorer quality) has already been interpreted; and if so, the extent to which the person who has interpreted the transmitted record can judge whether or not the primary record should be interpreted.

Utilization Measures under Conditions of System Overload. Another set of problems is concerned with system functioning under conditions of overload. In an emergency setting there never appears to be enough of anything. Studies are contemplated to provide information on the utilization of personnel under conditions of system overloads. Some of the studies are specifically intended to ascertain fatigue effects on interpreter output. What happens to interpreter output in a quick-time setting when the interpreter is kept continuously busy for 6, 8, 10, 12, 15 hours or more? What rest periods, if any, are needed? What should be

their duration, and at what intervals should they be given? Other studies in this area may also help find constriction points and thus may have an impact on the design and manning of the facility.

Psychological Factors in Coordinate Location of Enemy Forces. A thorough study is contemplated to define research problems dealing with the location, in terms of coordinates, of objects of interest identified by the interpreters. The effort to provide coordinates often becomes somewhat time-consuming. It is the intent of this study to see if research can be usefully employed to cut this time. Initially, performance will be observed to identify problems encountered by interpreters. If on the basis of these observations techniques can be developed that show promise of cutting the time to provide coordinates, these techniques will be put to an empirical test.

Development of Probability Intelligence. A final research area within this subtask deals with the development of "probability intelligence". In a combat setting, the commander must make decisions on the basis of fragmentary intelligence information, only partly accurate and at times delayed. To what extent can the product of the interpreter in the near real-time setting be used to extrapolate this probability intelligence? Fortunately, accuracy goes down as a function of time, that is, the first quick identifications made by the interpreter tend to be more accurate than later identifications (Zeidner, Sadacca, and Schwartz, 1961). This fact holds out the promise that probability intelligence based on quick-time interpretation may be quite good.

The initial study is planned as a feasibility study. If the study should demonstrate the feasibility of developing useful probability intelligence, steps can be taken to do so. The approach to these studies depends heavily on the availability of two similar performance measures with known ground truth. The photography of one performance measure would be given to interpreters for information extraction under quick-time conditions. The information these interpreters extract will be related to the ground truth, that is, for those items that they identify, (and these items can be presumed to be relatively easy) proportionality constants will be developed to adjust for the information the interpreters have failed to provide.

Taking each type of object separately in each of several pertinent settings, associations will be made between the type of object interpreters have succeeded in identifying and those they have failed to identify. For example, if interpreters with some consistency were to report a single tank on a photograph and fail to report three other tanks and an armored personnel carrier, the multipliers for the single tank would be 4 (tanks) and 1 (personnel carrier). The proportionality constant could vary for different terrain and climatic conditions. These proportionality constants will then be applied to the information provided by the interpreters upon interpretation of a second performance measure. Should there be an enhancement in performance due to the application of these proportionality constants, continued pursuit in this area might be quite rewarding.

It is recognized that probability intelligence will not include specific coordinates. Nonetheless, the knowledge of the existence of a force of a given strength within a limited area can be quite useful in and of itself. Moreover, when confronted with mobile enemy forces, the commander rarely knows that these forces are still deployed as reported by the time the report is given to him, and thus probability intelligence may be just as good, from the point of view of location, as other perishable information extracted directly from the photographs.

Techniques for Interpreting TV Imagery

The use of TV as an intelligence sensor has been considered repeatedly because it offers the possibility of 'real-time' observation. Actual progress has been slow in the development of the TV sensing capability for intelligence purposes for the following reasons:

1. the relatively small size of the "window" through which the ground is seen.
2. the relatively poor resolution of the TV image
3. the problem of providing coordinate information for objects that have been identified.

From a psychological point of view, there is some question as to just how much information TV can provide. It is not likely that a vertical mounting of the TV camera will provide much useful information unless the sensor platform flies high, and here the image resolution will probably be inadequate for interpretation. If it flies low, the ground appears to flit by--also inadequate for interpretation. Hypothetically the only objects observable under these conditions are very large and distinct objects. The forward oblique mounting seems to offer the best possibilities for the use of TV as an intelligence sensor, but even with this mounting, the limitations of TV hold down any expectation that this sensor will provide useful images.

Nevertheless, an initial study has been projected to determine whether or not TV-type interpretation is at all feasible. The TV display will be simulated by means of movie film having much better image quality characteristics than TV. If interpreters are not able to extract information from a medium that simulates TV but has a much better image quality, then the TV capability for intelligence purposes need not be considered further.

Improved Procedures in Communication of Intelligence Information

The problem of communication in an intelligence system can be divided into two major areas, one having to do with the meaning of language, the other with the flow of information to, from, and within the system.

A Standard Interpreter Language. Although the Army Intelligence School does teach its students a common language, current reporting procedures are loosely structured. Interpreters are allowed to report in their own words. Since many words have different meanings to different people, communication suffers in this kind of setting. The development of a standard reporting language and its use therefore become important.

Moreover, it becomes mandatory in a setting where computers are used for the purpose of storage and retrieval of information. Thus the language must have the additional property of being easy to code and to translate into machine language.

The intent of research in this area is to develop a standard interpreter language together with a code that is generally acceptable to computers. A tight language is less susceptible to misinterpretation than the current one, and one amenable to computer use, for the time when computers become available to the interpreter team.

Information Flow. Intelligence information can be thought of as belonging to two categories--hard-core, and perishable. Hard-core intelligence is that which does not lose timeliness readily. Terrain features, road networks, built-up areas belong in this category. Perishable intelligence, on the other hand, deals with information primarily involving enemy movement. Both categories of intelligence are important to the commander. As a rule, hard-core intelligence is stored. It should be relatively easy to retrieve and display to make it most useful. Perishable intelligence also may be stored, but more often it is obtained for immediate use.

The projected research in this area is intended to analyze the flow of information required to make both types of information--hard-core and perishable--available to the commander. Initially, the research will be restricted to interpreter intelligence information. The flow of information will be traced from its sources, through processing of the data, until the final products reach their destinations. An exploration of information flow may help define experimental problems, the solution of which may improve the communication of vital information.

CURRENT RESEARCH STATUS

The Task has already collected data for a study on the relative effectiveness of positive transparencies, negative transparencies, and positive prints (stereo and non-stereo). These data are being analyzed and the study should be completed during the first quarter of FY 63.

Currently, the Task is primarily in the tooling-up phase. Until now the main effort has been directed toward the development of meaningful problems and research approaches, and the construction of performance measures.

In developing performance measures, World War II photography was studied at the Aeronautical Chart and Information Center for appropriateness to the planned studies. Based on a thorough review of pertinent photo indexes, 57 rolls of negative transparencies were ordered and reviewed in the APRO laboratories. Preliminary interpretation was made on each roll. Results of interpretation were then compared, and 21 rolls selected for further use. Three distinct geographic locations are covered by the selected photographs. The necessary maps were secured, sortie plot overlays were completed, and general scenarios providing the setting were written. Six of the rolls in one of the areas were subjected to detailed interpretation for purposes of scoring key development. These rolls were also reproduced as positive transparencies, the selected mode for the studies on quick-time interpretation scheduled for the second quarter FY 63. The necessary detailed scenarios for these six performance measures are still to be written. (Further discussion of performance measure development is presented in the Appendix.)

Initial steps have also been taken for the construction of special light tables that permit determining the amount of time an interpreter spends in viewing each frame, and controlling the speed with which each frame is exposed to the interpreter. These light tables are required for the studies on interpreter performance under quick-time conditions.

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APPENDIX A

APPROACHES TO SYSTEMS RESEARCH

In developing concepts specific to the research undertaken by the IMAGE SYSTEMS Task, some concepts have evolved which also have some general applicability in other psychological research that is systems oriented.

A system can be thought of in terms of structure and function. It consists of equipment, materials, environmental conditions, personnel, and activities. It receives input, performs operations, and provides output. The output, if well-defined and measurable, provides the means for assessing the system.

A system can also be thought of as consisting of subsystems, each having its own input and operations, and its own output which in turn funnels into the larger system. The subsystem--and it is by improving the subsystem that the effectiveness of the total system can be increased--can be assessed in terms of two criteria, its own output and that of the total system. The real determinant of a subsystem's effectiveness is, of course, its contribution to the total system. This is particularly true when there are many subsystems, and when interaction effects among subsystems must be considered.

In some situations, however, subsystem output can itself serve as a criterion of subsystem effectiveness, a consideration that is important for two reasons: (1) If a measure of total system output cannot be obtained, and it can be assumed that the subsystem contributes to total system effectiveness, a measure of subsystem output can be employed to determine how changes in the subsystem (in work method, for example) would affect output. If two subsystem procedures are found to yield identical subsystem outputs, then the cheaper and simpler of the two will obviously contribute as much to total output as the more complex. (2) A second reason for making use of the subsystem measure is that it may be highly relevant to the determination to be made and at the same time cheaper and easier to obtain.

Tests of system effectiveness require measures of system output. These measures must reflect Army needs which these systems are designed to meet. The Army requires accurate, complete, timely, and relevant intelligence information. These output requirements are multi-dimensional; system output therefore cannot be best described in terms of a single over-all measure. Speedy information extraction may sacrifice accuracy and completeness. Accurate information extraction may sacrifice speed and completeness. Similarly, completeness of extraction or information may sacrifice speed and accuracy. Systems performance must, then, be measured in terms of each output dimension, and perhaps also in terms of a joint function if such a function can be developed.

In systems research, studies can be conducted on "real" systems, "simulated" systems, or "hybrid" (partly real and partly simulated) systems. Whenever simulated or partly simulated systems are used, these systems must approximate the real systems in all critical aspects. Whether or not any of these three types of system is employed depends upon whether or not

the real system is available for study

the research cost is favorable to one or the other

the critical factors under consideration are subject to control in the various settings.

In addition to the problem of real vs simulated systems, there is also the problem of real vs simulated input into the system. The factors of availability, cost, and control of critical factors also apply in deciding between real and simulated input. In this connection, there is the problem of determining the characteristics of the input. If these characteristics are not specifically known--and this is often the case--it is very important to vary the range of the simulated input characteristics to be sure that the research has applicability to the projected system.

From a systems development standpoint, the desired structure of a system is the simplest one that will meet the output needs. Therefore, in the development of a system it seems most logical to begin with the simplest structure and build from there. This means that only the barest essentials are provided. An input is fed through the system and the output is measured. If for any reason the system is non-functional, the point of difficulty can be identified readily, and the system can be modified. Once the system is known to work, the quantity, sequence, rate, and kind of input can be varied to determine points of constriction. Modifications can be developed to take care of bottlenecks. More personnel, equipment, etc., can be made available to expedite the work flow. If alternate modifications are possible, they can be compared in a controlled test. Similarly, work aids and procedural changes can be introduced and their effects on system output noted.

The use of a functional system with the simplest possible structure has a great contribution to make to system research, providing a standard against which the output of other more complex systems can be assessed. However, the use of the simplest possible structure is often not feasible. More complex, more flexible systems may already be in existence and may have "proven" themselves. In this case the existing system can be used as the standard against which future systems will be evaluated.

System complexity poses another problem that all too often is overlooked. System developers try to meet Army needs by developing more and more complex and sophisticated systems. In some instances, the human link is automated completely out of the picture. Or the requirements imposed upon the human link may become more demanding and more burdensome. In the latter case, a serious problem is created from the point of view of

availability of personnel to meet the various system needs. As more systems require greater human skills, abilities, and talents to make the systems functional, the problem will become more acute since the individuals with the requisite attributes are limited in number.

Apart from the problem of manpower availability, complexity of systems and tasks raises the question "What is the gain and what is the cost of the complex system?" Or stated differently, "what is the net gain?" This question is raised not so much from the point of view of the development of the system or its dollar cost as from the standpoint of the system's use. For example, a simple picture-taking system may consist of a man (the photographer) and a simple box camera loaded with film. The system permits the man to take pictures only during daylight hours with the subject at least ten feet from the camera. In order to take the picture, the photographer must advance the film to a designated mark, cock the camera shutter, point the camera by means of the viewer and then snap the picture. In a more sophisticated system the camera may have a focusing adjustment and shutter adjustments permitting variable lens openings and shutter speeds. The latter system provides greater flexibility and the opportunity for better pictures. On the other hand, it requires greater skill on the part of the photographer. It also imposes a greater training requirement. In addition, there is more opportunity for error and greater likelihood that equipment will malfunction and the camera become non-operable. Above and beyond the problem of "down" time, there now exists the increased demand for highly qualified technicians to repair the camera, coupled with the increased logistical problem of maintaining a supply of necessary spare parts. It may well be that in terms of overall needs the less sophisticated system is better. This argument, however, must not be construed to be an argument against complex, sophisticated systems, because many needs can be met only by such systems. Rather, the argument points to the requirement for assessing systems in terms of real and pervasive Army needs on the one hand, and complexity requirements on the other. In assessing systems, the point of diminishing returns must be kept in mind.

Problem definition and problem selection pose yet another problem in systems research. Prerequisites are a thorough understanding of the needs and purposes of the system under study and a detailed knowledge of the system in terms of input, operations, equipment, personnel, and environmental conditions. Even with this knowledge there remains the question "How do we know that we have selected a problem the solution of which will result in an improvement in the system's output?" This question takes on special significance when research is done on subsystems. A tremendous improvement in the output of one subsystem may have a negligible effect on total system output. A much smaller increment in the output of a different subsystem may improve total system output appreciably. There is very little methodology available to help in problem selection. The researcher must work very closely with the experts in the field to identify problems on which research can profitably be conducted. He must then make a number of additional determinations: Is the problem researchable? Is the necessary equipment in existence? If not, can it be built or simulated in time for the research results to be useful? Are input materials available? Is personnel available to serve as subjects for the experimentation?

Systems have been analyzed in terms of structure and function, where function is expressed in terms of Army needs. They have also been analyzed in terms of subsystem vs total system. This was done in order to establish criteria for the assessment of system effectiveness. For the systems under consideration in the IMAGE SYSTEMS Task, the output factors are accuracy, completeness, and timeliness of information extracted from the images. The concept of the simple system as standard against which to assess more complex, sophisticated systems has also been developed. Approaches adopted deal with input and system simulation.

APPENDIX B

DEVELOPMENT OF PERFORMANCE MEASURES

Among the major tools of the researcher in systems work are performance measures, or work samples through which measures of output or system effectiveness are obtained.

In the Image Systems area the desired output is intelligence information. In order to derive this intelligence, the interpreter examines images, extracts the desired information, and reports it. A performance measure thus consists of an input of imagery which the interpreter analyzes in order to provide information, plus a standard procedure for evaluating output. For a performance measure, the output must have the property of being measurable. The opportunity must exist for determining whether each of the responses the interpreter makes is correct. Therefore, the intelligence content of the imagery input must be known to the researcher although not to the photointerpreter examinee. This concept constitutes the basis for the performance measure development for image systems research.

There are, of course, other requirements. Since the intent is to generalize findings to the military setting, the imagery should represent in content and quality materials that include items of military significance. The imagery must be specific to the studies to be conducted. Appropriate imagery may sometimes be selected from available World War II or Korean photography runs, or it may be necessary to have missions run to obtain it. The imagery material should be displayed in the proper format and in the proper setting. Tasks normally established by mission requests should be duplicated. In fact, the performance measure as such cannot be separated from the system being studied. In order to make proper assessments, all critical factors of the system or subsystem, of the imagery, and of the requirements, must be duplicated.

Separate measures of accuracy, completeness, and timeliness may be desired. Timeliness as such cannot be readily measured since timeliness imposes a requirement beyond the control of the interpreter. For example, if an interpreter identifies, locates, and reports a group of enemy tanks within one hour after he has received the image, the information will be timely only if the tanks have not moved in the interim. However, speed of information extraction, which can be easily measured in terms of seconds, minutes, and hours, bears a relationship to timeliness. The likelihood that the information is timely goes up as the time interval between the sensing and reporting of the information goes down. Thus, speed of information extraction may be a useful component of a measure of system effectiveness.

Measuring the accuracy and completeness of information extraction poses a somewhat different problem. Here the focus is on the specific nature of the responses made by the interpreter. The interpreter confronted with an image can make correct identifications (rights) or misidentifications (wrongs). The interpreter can also fail to make

responses where he should (omits). An interpreter's performance can thus be measured in terms of rights, wrongs, and omits. These measures in and of themselves do not constitute measures of accuracy and completeness. However, they provide a basis from which such measures can be derived.

Accuracy of information extraction relates rights to wrongs. It can be expressed as the ratio $\frac{R}{R + W}$ where R represents the number right and W the number wrong. Completeness of information extraction relates rights to numbers of objects to be identified in the imagery as established by "ground truth." It can be expressed as the ratio $\frac{R}{K}$ where R again represents the number right and K represents the number of objects desired for identification.

A breakout of performance into components of accuracy and completeness is important from the point of view of assessing system effectiveness. Under one set of conditions, the system may provide information that is accurate but relatively incomplete. In another, the reverse may be true. With the focus on accuracy, an interpreter may report only those objects of which he is absolutely sure. For example, of 50 identifiable objects on an image he may report only two, getting both of them right. His accuracy would be $\frac{2}{50}$ or 4%. His completeness would be $\frac{2}{50}$ or 4%. With the focus on completeness, on the other hand, the interpreter might report 100 objects, 25 of which are right. His accuracy then would be $\frac{25}{100}$ or 25% and his completeness would be $\frac{25}{50}$ or 50%. Which, then is better, performance with 100% accuracy and 4% completeness, or performance with 25% accuracy and 50% completeness? The answer depends on the commander's needs. If the commander has sufficient fire-power to cover a large area with fire, he might want to stress completeness. On the other hand, if his fire-power is limited, he might want to emphasize accuracy. From the foregoing it is evident that there may be trade-offs between accuracy and completeness and similar trade-offs that involve speed of interpretation. Knowledge of the functional relationships existing among accuracy, completeness, and speed of interpretation may provide the commander with trade-off information that could help him in making the best use of his intelligence system.